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955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

B69 09073

SUBJECT: Maximized Manned Earth Applications Program Case 234

DATE: September 9, 1969

FROM: W. L. Smith

[redacted]

ABSTRACT

This study considers maximum manned support of the earth applications program. In contrast to the National Academy Summer Study recommendations for a totally automated program, we find the arguments for manned support to have been understated, and that these will become stronger as both the applications program and manned capabilities develop. It is found that a program based on two sets of orbital stations -- a set of two or three manned or man attended stations in low altitide, near-polar orbits, and a set of three automated, man attended stations in geo-synchronous orbits -- would fulfill about 80% of the requirements of a comprehensive sensing program of the future. The advantages of manned support would be rapid system development, film supply and return, specialized manned studies from space, and versatile long-level maintainable systems of large payload and power capabilities that can grow fast enough to meet the increasing needs of a large applications program. Many of the requirements are common to the fulfillment of other agency goals, large costs would be shared, and the returns to the applications program could be more cost-effective than a separate, totally automated program.

(NASA-CR-106777) MAXIMIZED MANNED EARTH APPLICATIONS PROGRAM (Bellcomm, Inc.) 24 p

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MEMORANDUM FOR FILE

I. INTRODUCTION

The survey and monitoring of the earth's resources from space satellites promises enormous benefits to mankind.[1-4] To implement such an "earth applications" program the National Academy - National Research Council Summer Study[1] recommends a vigorous automated program, while the STAC Winter Study[3,4] indicates that substantial advantages could accrue from use of a well-developed manned space capability.

Developments to date of space applications systems go back to either purely manned or purely unmanned systems. In Figure I, in the period of Phase I (up to FY '70), nearly all applications experiments will have been unmanned (Tiros, Nimbus, ATS, ERTS). In Phase II (FY '72-'75), manned programs of significant extent are possible in the applications areas. By Phase III (1980-85) several manned stations may exist in earth orbit, and may carry the majority of experiments and operational sensors, while the Earth Resources Satellite (ERS) may continue as an unmanned supplement to the program.

For the future beyond Phase III, where the hoped-for all-embracing management system from space will be a reality, a dominant manned station role is a possibility. Such stations would use unmanned subsatellites and put all the experience from earlier space stations and from ERTS-ERS to good use.

The present study considers the question, "If the manned program is designed to provide maximum support to earth applications, what would the resulting system be, and what are its capabilities and costs?"

We make four assumptions:

a. The manned program now starts to put heavy emphasis on supporting earth applications;

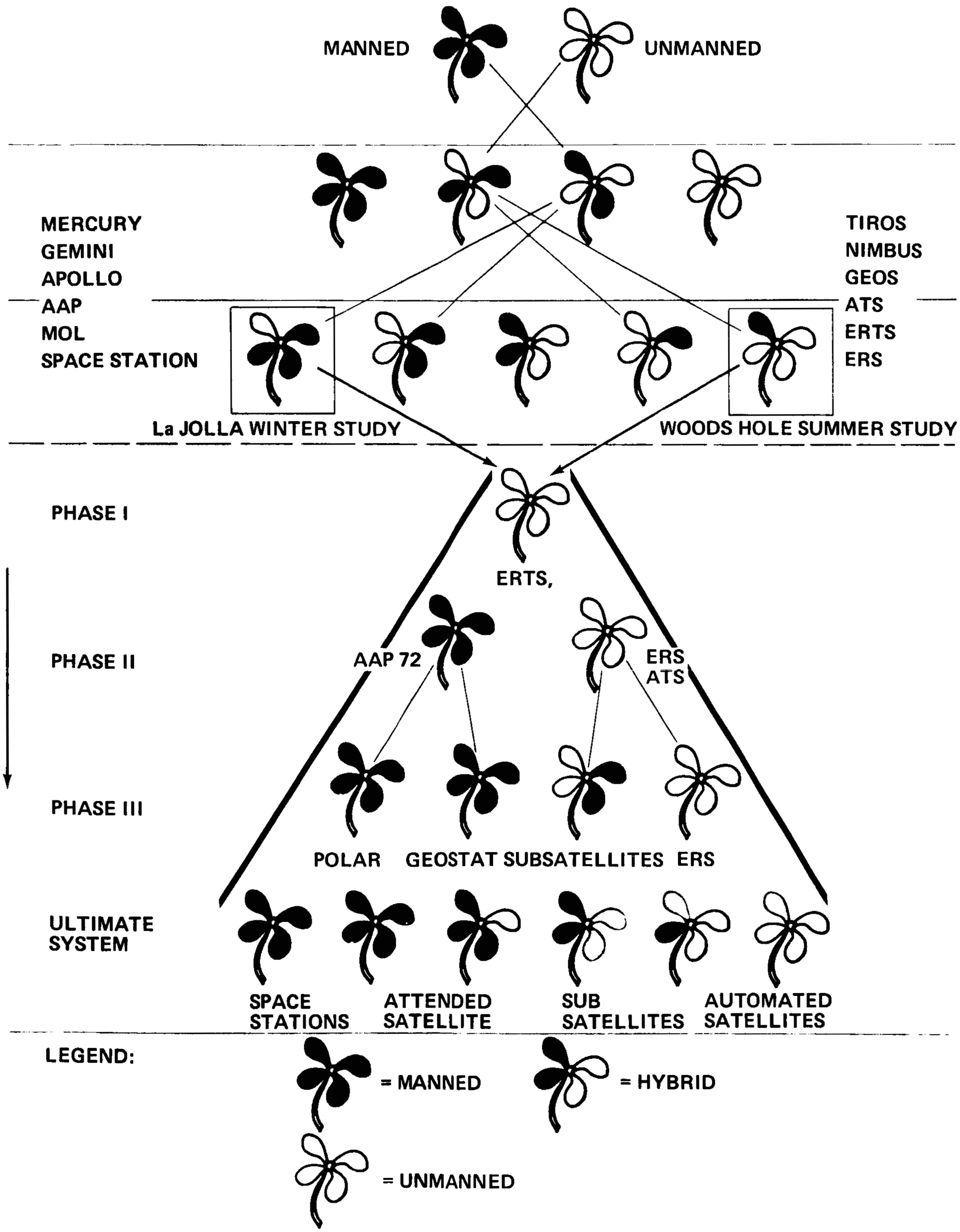


FIGURE 1 : FLOWER CHART
(CHOICES BETWEEN MANNED AND UNMANNED PROGRAMS)

b. Starting after 1975, a set of multi-disciplinary manned space stations will be put into permanent orbits, with relatively cheap logistics for transport of men and supplies to stations or to visit automated satellites;

c. Funding will be available for rapid development of remote sensing systems for test and use on manned stations;

d. A data management and use system can be developed in time to meet the requirements of all users.

Using these assumptions, in the following sections we will summarize the projected overall requirements for earth sensing systems, describe a principally manned program to meet these needs and examine briefly the costs and schedules involved.

II. FUTURE REQUIREMENTS OF EARTH APPLICATIONS SYSTEMS

Table 1 is a summary of the principal future requirements as currently foreseen, for satellites and other systems to gather data in all disciplines. Detailed discussions of requirements and benefits expected are given in the sources.(1-4) A significant conclusion from Table 1 is that about 80% of all sensing requirements can be satisfied by a few satellites in two types of orbit - the first low-altitude, near-polar, and the second geo-synchronous. In fact, the only requirements not thus met are for geodetic satellites that need very low inclination, low altitude orbits, and for balloons, buoys, ground-based hydrologic and seismic sensors and localized aircraft surveys.

The requirement sometimes stated for meteorologic satellites at 600-2000 miles altitude arises because meteorologists need sequential lateral ground track overlap with complete global coverage daily for cloud photographs, and coverage on several sequential passes daily of all balloon transmitters for wind measurements. It will be shown below that equivalent coverage with improved resolution is achieved for all purposes but balloon tracking with multiple near-polar, low-altitude satellites. Until better wind measurement techniques are devised, tracking of balloons may require a few automated satellites at 600-2000 miles altitude.

TABLE 1 - TOTAL FUTURE SYSTEMS REQUIREMENTS

	NEAR POLAR LOW ALT 150-250 NM	NEAR POLAR MED ALT 500-2000 NM	LOW INCLINATION	GEOSYNCHRONOUS	OTHER SUPPORT
METEOROLOGY	2 OR 3 SAT'S SOUNDINGS 400 KM HORIZ IR RADIOMETRY RES'N IR AND MICROWAVE IMAGERY 2KM RES'N DAILY COVERAGE	1 OR 2 SAT'S BALLOON LOCATION AND READOUT FOR WIND VELOCITY		4 SAT'S CLOUD COVER COLOR PHOTOGRAPHY .5 TR IMAGERY, 3 KM DATA RELAY	SEVERAL THOUSAND BALLOONS AND BUOYS
OCEANOGRAPHY	2 OR 3 SAT'S PHOTOGRAPHY IR AND RADAR IMAGERY IR RADIOMETRY TO SCATEROMETRY 10 KM LASER ALTIMETRY BUOY RADOUT RES'N			3 SAT'S IR IMAGERY DATA RELAY	BUOYS SHIPS
HYDROLOGY	3 SAT'S MULTISPECTRAL PHOTOGRAPHY, 20M IR AND RADAR IMAGERY, 10 KM READOUT OF GROUND SENSORS			3 SAT'S DATA RELAY	10,000 TO 40,000 GROUND SENSORS
AGRICULTURAL/FORESTRY	1 SAT. MULTISPECTRAL PHOTOG., 20M MICROWAVE RADAR IR IMAGERY			DATA RELAY SATELLITE	AIRCRAFT HIGH RESOLUTION PHOTOGRAPHY AND RADAR AND IR IMAGERY
CARTOGRAPHY/GEOGRAPHY	1 SAT. METRIC CAMERA 12 M RESOLUTION ANNUAL COVERAGE				AIRCRAFT HIGH RESOLUTION PHOTOGRAPHY
GEOLOGY	1 SAT. COLAR PHOTOGRAPHY, 30 M LOW SUN ANGLE IR AND MICROWAVE IMAGERY				AIRCRAFT SIDE LOOKING RADAR SUBSYSTEM HIGH RESOLUTION PHOTOGRAPHY
GEODESY (EARTH PHYSICS)	DESIRABLE IN FUTURE	2 SAT'S. LASER REFLECTORS DOPPLER DEVICE	1 SAT. 15° INCLINATION ELLIPTICAL, HIGH ECCENTRICITY		AIRCRAFT HIGH RESOLUTION PHOTOGRAPHY BAKER-NUNN TRACKING
COMMUNICATIONS				1-3 OR MORE SAT'S FOR DATA COLLECTION AND BROADCASTING DOMESTIC AND INTERNATIONAL	LARGE NUMBER OF GROUND STATIONS
NAVIGATION/TRAFFIC CONTROL				2 SAT'S GEOSTATIONARY COVERING N. ATLANTIC AND PACIFIC FOR AIR AND SEA TRAFFIC AND RESCUE	SUPPORT FROM SHIPS, BUOYS

*AS SPECIFIED IN NAC-NRC SPACE APPLICATION SUMMARY STUDIES' 1967, 1968
AND OTHER SOURCES: REFS 1-5

III. DESCRIPTION OF PROPOSED MANNED SYSTEM FOR 1975-1985

A. General Characteristics

Scope: This program is envisaged to grow in time with the addition of manned stations after 1975 to support the major sensing requirements of all applications disciplines.

Nature of System: Most space sensors will be supported by modules nearby or attached to two sets of manned orbital stations. The first set will consist of two or three near-polar, low-altitude stations at least one of which would be permanently manned, while the second will be three geo-synchronous stations visited and serviced by man at six months to one year intervals (Figure II). Certain automated satellites, subsatellites controlled by the stations, balloons, buoys, ground sensors and aircraft will complete the sensing system.

Mode of Operation: Routine sensing and data handling in the operational system will be handled automatically by the sensors and systems supported by the space stations. Such systems will be serviced and maintained as needed by man. New supplies and film will come from the earth on a regular basis.

The near-polar, low-altitude stations in addition to their automated sensing operations, will serve as test and development stations for new sensors and provide specialized sensing equipment for scientific manned studies of the earth and its atmosphere.

The geo-synchronous stations will operate unmanned, but will be serviced by men who will shuttle from one of the three stations to the others. One station may eventually need to be occupied by a 3-man crew on a full time basis, with a six months to one year resupply schedule.

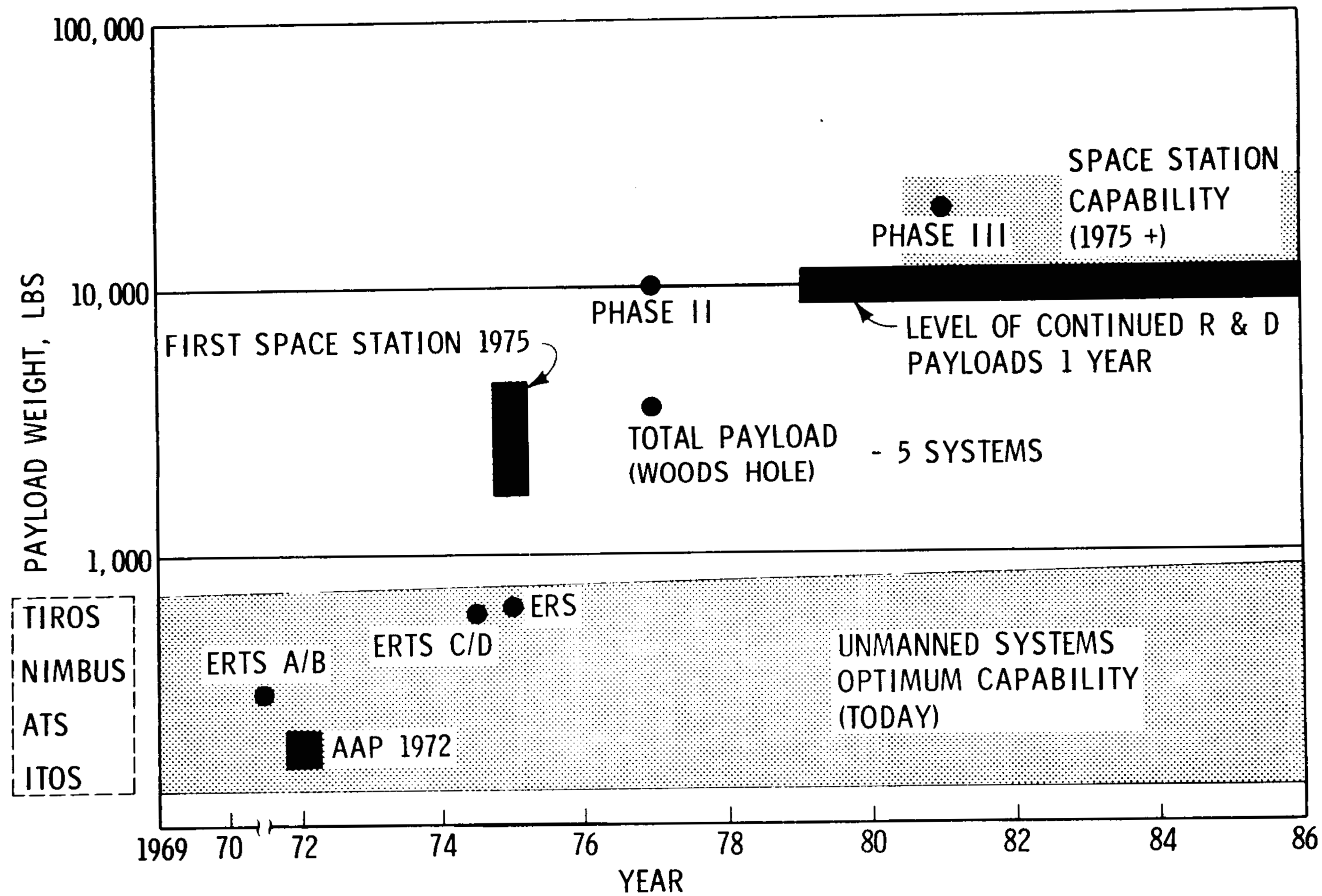
B. Detailed Systems and Functions (Table 2)

Near-Polar, Low Altitude Stations: The essentials of this set of manned stations will be

a) High (near-polar) inclination to achieve global coverage;

b) Low-altitude, 150 to 250 miles, to achieve high resolution sensing;

FIGURE II



GROWTH OF EARTH SURVEY PAYLOAD REQUIREMENTS

TABLE 2- PROPOSED MANNED SPACE SYSTEM; CONTINUOUS CAPABILITIES

	NO. OF SATELLITES		PRIME INSTRUMENTS	RESOLUTION	INSTRUMENT WEIGHT, POUNDS EACH SATELLITE	FREQUENCY COVERAGE	DATA REQUIREMENT	OTHER SYSTEMS
	NEAR-POLAR 150-200 NM	GEOSYNCHRONOUS EQUATORIAL						
METEOROLOGY	2 OR 3 SUN SYNCH	0	MICROWAVE RADIOMETER IR IMAGERY, SPECTROMETER IR RADIOMETER LASER SOUNDER READOUT OF BALLOONS	2 TO 100 KM	800	GLOBAL COVERAGE DAILY	TELEMETRY READOUT OF ALL SENSORS DAILY, SOME EVERY 6 HOURS 10^{10} BITS/DAY	
		3	COLOR PHOTOGRAPHY IR IMAGERY FOR CLOUD COVER DATA RELAY	.5 KM 2 KM	100	4/DAY 2/DAY	TELEMETRY - 10^{10} BITS/DAY	CONSTANT ALTITUDE BALLOONS AND BUOYS
OCEANOGRAPHY	2 OR 3 SUN SYNCH	0	IR IMAGER RADAR SCATTEROMETER RADAR IMAGERY LASER ALTIMETER IR, VISIBLE SPECTOMETRY SHORE & HARBOR PHOTOG READOUT OF BUOYS, SHIPS	2 KM 20 m	800	GLOBAL COVERAGE DAILY	TELEMETRY - 10^{10} BITS/DAY 100 LBS FILM/MONTH	SHIPS, BUOYS
		3	IR IMAGERY RADAR IMAGERY	2 KM	200	DAILY	TELEMETRY - 10^{9} BITS/DAY	
HYDROLOGY	1	0	MULTISPECTRAL PHOT. IR IMAGERY DATA RELAY READOUT OF SENSORS	20-200 m	500	MONTHLY	MONTHLY TELEMETRY READOUT 50 LBS FILM/MONTH MAGNETIC TAPE STORAGE	SOME AIRCRAFT COVERAGE 10,000 - 40,000 GROUND SOURCES
AGRICULTURE/FORESTRY	1	0	MULTISPECTRAL CAMERAS MICROWAVE IMAGERY IR IMAGERY MW IMAGERY	30 m	500	WEEKLY	WEEKLY TELEMETRY READOUT 100 LBS FILM/MONTH LARGE MAGN. TAPE STORAGE	SOME AIRCRAFT COVERAGE
CARTOGRAPHY GEOGRAPHY	1	0	METRIC CAMERA	12 m	200	SEASONAL	500 LBS FILM RETURNED/MONTH	SOME AIRCRAFT COVERAGE
GEODESY (EARTH PHYSICS)	2	0	LASER REFLECTORS DOPPLER DEVICES	1 MILLIGAL	30	ONCE ONLY	LOW BIT RATES (GROUND TRACKING)	BAKER - NUNN CAMERA TRACKING NOTE: UNMANNED SATS NEEDED IN OTHER ORBITS
GEOLOGY	1 LOW SUN ANGLE SUN SYNCH	0	COLOR PHOTOG MULTISPEC CAMERA IR IMAGERY MW IMAGERY RADAR IMAGERY	30 m	600	ONCE ONLY FOR ONE SET OF SEASONS	500 LBS FILM/YEAR TELEMETRY READOUT MONTHLY	SOME AIRCRAFT COVERAGE SIDE LOOKING RADAR
TOTAL SC REQ'TS	3 SATELLITES (NEAR POLAR)	0	EACH SATELLITE: 15 INSTRUMENTS 10 SHARED BY TWO OR MORE DISCIPLINES	30 m	EACH SAT.: 3000 LBS TOTAL FOR 3 SAT'S 9000 LBS WITH SUPPORT WT 18,000 LBS	GLOBAL DAILY	EACH SATELLITE: 800 LBS FILM/MONTH TELEMETRY AT 10^{11} TO 10^{12} BITS/DAY	
	0	3 SATELLITES (GEOSYN-CHRONOUS)	EACH SATELLITE: 4 INSTRUMENTS	2 KM	EACH SAT.: 700 LBS TOTAL: 2100 LBS WITH SUPPORT WT 1000 LBS	GLOBAL 4 TIMES DAILY	EACH SATELLITE 10^{11} TO 10^{12} BITS/DAY SOME HARD FILM EACH 6 MO'S	

c) Use of two or three stations to provide frequent coverage (every day or two) of the entire earth, even near the equator. (The multiple station concept also adds program flexibility, the possibility of two or three lighting angles for sun-synchronous orbits, and the possibility of flying complementary instruments on the different stations.)

Sun-synchronous orbits at 220 n.mi. altitude (near-polar) seem attractive. With the correct choice of phasing between the two orbital planes and positions, one can assure repetitive daylight coverage of every ground point at the equator every two days with constant illumination using 45° half-angle sensors with two satellites. If we use three polar stations instead of two, we obtain full global daylight coverage every day. For instruments requiring much less than 45° half-angle coverage, full global coverage is still possible over a period of weeks choosing an orbital frequency that causes the ground tracks to move slowly over the earth's surface. Frequency of coverage by polar satellites will always be poorest at the equator and improve toward the poles.

The principle instruments to be used on the near-polar stations will include

1) High resolution multi-spectral cameras for global land use analysis.

2) IR Imagery, to serve oceanography, meteorology, agriculture, forestry and geology.

3) Radar Scatterometry to supply sea-state of the oceans.

4) Radar Imagery to penetrate cloud cover.

5) IR and microwave radiometry to measure atmospheric profiles.

6) Specialized sensors for manned studies, such as spectroscopic and laser atmosphere studies, high resolution photography, spectrometry or temperature analysis of storms, cold fronts, pollution sources, volcanoes, etc.

All these instruments would be housed in a manned module, itself part of a space station, with attitude stabilized to provide continuous earth-looking orientation.

Shuttles from the earth would bring up about 1000 lbs of magnetic tape, film and new instruments every month, and rotate 3 of the 6-9 man crew. Specialists in earth science fields could visit the station for tours of observational duty.

Geo-synchronous Stations: The essential properties of the three equatorial geo-synchronous stations at 120° for earth applications will be

a) Continuous coverage of all the earth's surface up to about 60° latitude;

b) Continuous line-of-sight communications between the three stations and hence to any earth station.

The principal instruments on these stations will be

1) High resolution (2 km) multispectral photography every four hours for cloud cover (meteorology).

2) High resolution IR Imagery (for meteorology and oceanography).

3) Communications receivers and transmitters.

4) A possible addition would be color photography to provide films of selected targets for astronaut return at servicing intervals.

There appears to be little that a man can do while at geo-synchronous altitude that could not be done as well by remote automatic command of orientable cameras. Hence, the only role of man foreseen for the geo-synchronous station is deployment, calibration, maintenance and repair of operating systems. Since it is very costly, energy-wise, to launch men to geo-synchronous orbit, (a Saturn V is required for 3 men at present) one would at most man one of the three stations with 3 men full time, and revisit only each 6 months or a year.

IV. PROGRAM AND SCHEDULE TO ACHIEVE THE PROPOSED MANNED SYSTEMS

Specific objectives and requirements in earth sensing have been defined by the NASA planning panels and grouped into three phases of accomplishment. These are shown in Tables 1-3 in the Appendix.

A. Summary of Present Unmanned Program Plans

A schedule for the overall earth survey program is given in Table 3. It is reasonable to assume that the R&D effort of the applications program will normally have available facilities onboard space stations, even if the operational aspects of the program are unmanned. The possibility of accomplishing all applications R&D by aircraft and unmanned satellites would preferably be rejected in light of the considerable program necessary to accomplish the specific objectives of Phases II and III and, of the ultimate system within a limited time. We suggest two tentative conclusions in this area:

- Unmanned SR&T will be unable to lead to the ultimate program position of values in a reasonable time frame.
- Space station SR&T facilities for earth resources are imperative for the realization of the ultimate program.

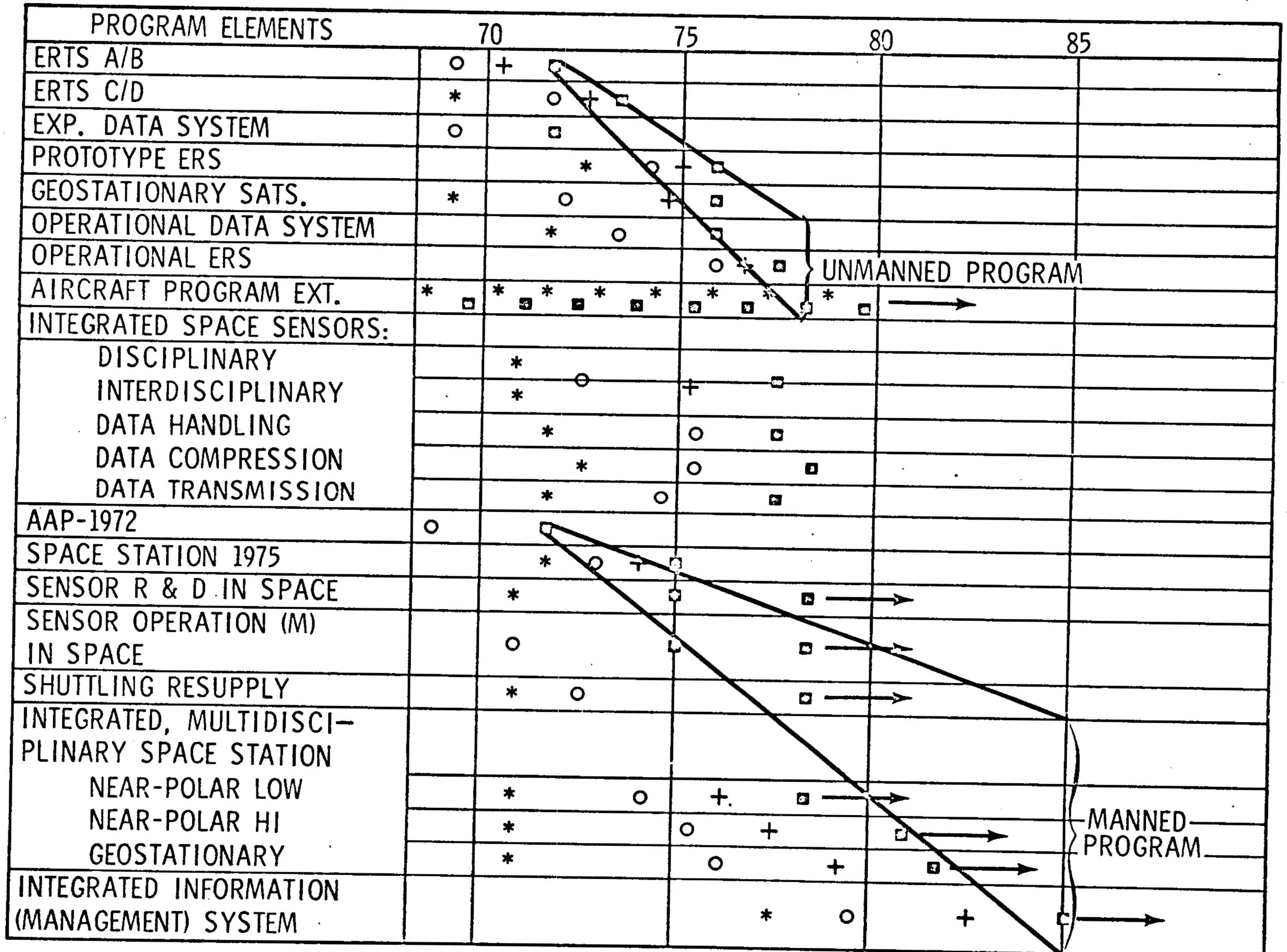
Table 1 in the Appendix depicts specific objectives of R&D in Phase I. With a total payload weight of 1400 lbs to achieve the objectives of Phase I, it turns out that four satellites such as ERTS would be required to handle the R&D workload. For lack of a manned program, it will be the total effort in Earth Resources Survey.

B. Plan to Emphasize Manned 1975 Stations (near-earth)

If the unmanned program begins to strain its capabilities within the first half of the 1970's, then a manned program offers itself as one reasonable alternative for earth survey. Reasonable specific objectives for a Phase II effort have been tabulated (Table 2, Appendix), and the total payload requirements for that phase add up to about 10,000 lbs.

It appears unlikely that a manned 1975 space station will be ready to support such a substantial earth survey payload. weight. Quite likely, up to several thousand pounds of sensors

TABLE 3 - SCHEDULE FOR OVERALL EARTH SURVEY PROGRAM (EMPHASIZING MANNED PROGRAM)



* - PHASE A-B (CONCEPT)

o - PHASE C-D (HARDWARE)

+ - PAYLOAD TESTING

□ - FLIGHT READY

→ - AND ON

will be flown by ERS and, possibly, user vehicles such as EROS. But it must be realized that an all-out program as indicated in Table 2 (Appendix) can only be carried out if the lion's share of the sensors is accommodated on a manned space station.

Decision Point: In order to reach the objectives of Phase II, by unmanned means, an order of magnitude increase in flight hardware over and beyond the presently planned system appears necessary. This means either an immediate new start in the 2,000 lbs category of unmanned satellites, or the availability of an earth resources facility of up to 10,000 lbs in manned stations by the middle to late 1970's.

C. Phase III Effort

The systems requirements for specific objectives of Phase III have been summarized in Table 3, Appendix. This is the first, predominantly operational complement of sensors, and consequently ground coverage, frequency and resolution requirements have increased. It will take about twelve payloads of 3,500 lbs each, or a total of some 40,000 lbs to achieve the effort of this level.

The planned effort - operational ERS and second-generation operational ERS - are out of line by about a factor of 30 to achieve the R&D and operational objectives needed.

The Woods Hole Summer Study projected that during a phase 2/3 type operation a number of satellites supporting different user disciplines would be in orbit simultaneously. Allowing for some commonality among all sensor uses, we wind up with 5 polar satellites and 3 geo-synchronous satellites in orbit at any time. The total payload capability of these satellites, allowing ERTS-ERS type payloads, would be about 5,000 to 8,000 lbs. From the specific objectives in the Appendix it follows that the payloads needed to support the Phase II and III requirements will be 10,000 to 40,000 lbs. Therefore, the already very busy launch schedule of a potential unmanned system, with 13 Atlas-Centaurs and 32 Thor-Deltas, can be assumed as being too short within a factor of 2 to 4.

To achieve objectives of Phase III, the payload should be tripled to about 10,000 lbs, thus reducing the required multiplicity of systems to about 4. Four manned stations, each accommodating about 10,000 lbs of earth survey payload and data handling experiments, could very well handle the Phase III sensing load that 36 1,000 lb ERS satellites could probably not handle.

It appears from this cursory analysis that the means may fall short of the goals of the earth survey program, and that manned stations can offer adequate support facilities for the required R&D and operational sensing tasks within the Phase I-III task frame.

D. A Phase III Manned Station Plan

For the Phase III effort, three distinct parts can be distinguished:

a) R&D - 10,000 lbs payload

b) ERS - several 1,000 lbs payload

c) Manned space station - several 10,000 lbs payload

The significant R&D payload onboard a manned space station would insure adequate development for future operational sensing. Such R&D can be expected to continue for several generations of future instruments.

The ERS payload, having acted as a forerunner and operational test payload, may continue to be operated, as a stopgap between manned missions and for routine observation at high orbital altitude that may be unattainable for manned missions of the late 1970's/early 1980's.

The manned space station facility will carry the brunt of the Phase III sensor and operational load possibly acting as "mother ship" for ERS-type subsatellites.

At the end of Phase II, and during Phase III (late 1970's), the boundaries between development work and operational sensing become vague. It is true that about 3/4 of the payload of 40,000 lbs during Phase III are devoted to operational type sensing. However, some 10,000 lbs of the payload can be considered truly R&D oriented, and an annual payload weight of that extent can be projected to be part of manned spaceflight for the foreseeable future.

It can be argued that a launch of a 10,000 lbs/year R&D payload sets the pace for the resulting operational systems, that will be of the order of 20,000 to 40,000 lbs. Clearly, this weight class is beyond the class of unmanned sensors that are in the minds of "unmanned planners" today.

Figure III shows a comprehensive earth survey system of the 1980's using manned or man attended satellites.

V. COSTS OF PROGRAM

A. Summary of Present Unmanned and Manned Program Plans:

There are diverse projections of program costs for manned and unmanned programs. In the series of "ball park numbers", the unmanned ERTS-ERS program is pegged at $500 million, while space station programs are ten to twenty times that much.

We have made a thumb nail calculation, using above ball park figures of $500 million for ERTS-ERS and $5 billion for the earth resources facilities onboard several space stations. If the ERTS-ERS program is assumed to operate for 5 years, yielding a bit rate of 10^{11} bits per day (limited by a payload capability of about 1000 lbs per satellite), then the ERTS-ERS cost per 10^6 bits runs $3.30.

If the manned space station program at $5 billion is assumed to last for ten years, delivering 10^{13} bpd (due to payload capability up to 15,000 lbs), then it can offer 10^6 bits for only $1.50.

Figure IV shows estimated costs for the total unmanned program including the ERS, and for the experiments payload on the manned program. The unmanned program costs are based on Space Applications Program Memorandum, Earth Resources Survey, 1968. Their total is estimated at approximately $500 million. The cost of the experiment payload for the manned program proposed in this study is about $400 million. The cost of modules to carry these experiments, plus a fair share of the manned station costs, brings total application costs to about $5 billion over the 10 year period.

B. A Manned (Phase III) Space Station System

Total costs for manned space stations have been projected by Schelke[6] to range in the order of $5 billion to $10 billion, over a 10 year period. A significant part of the

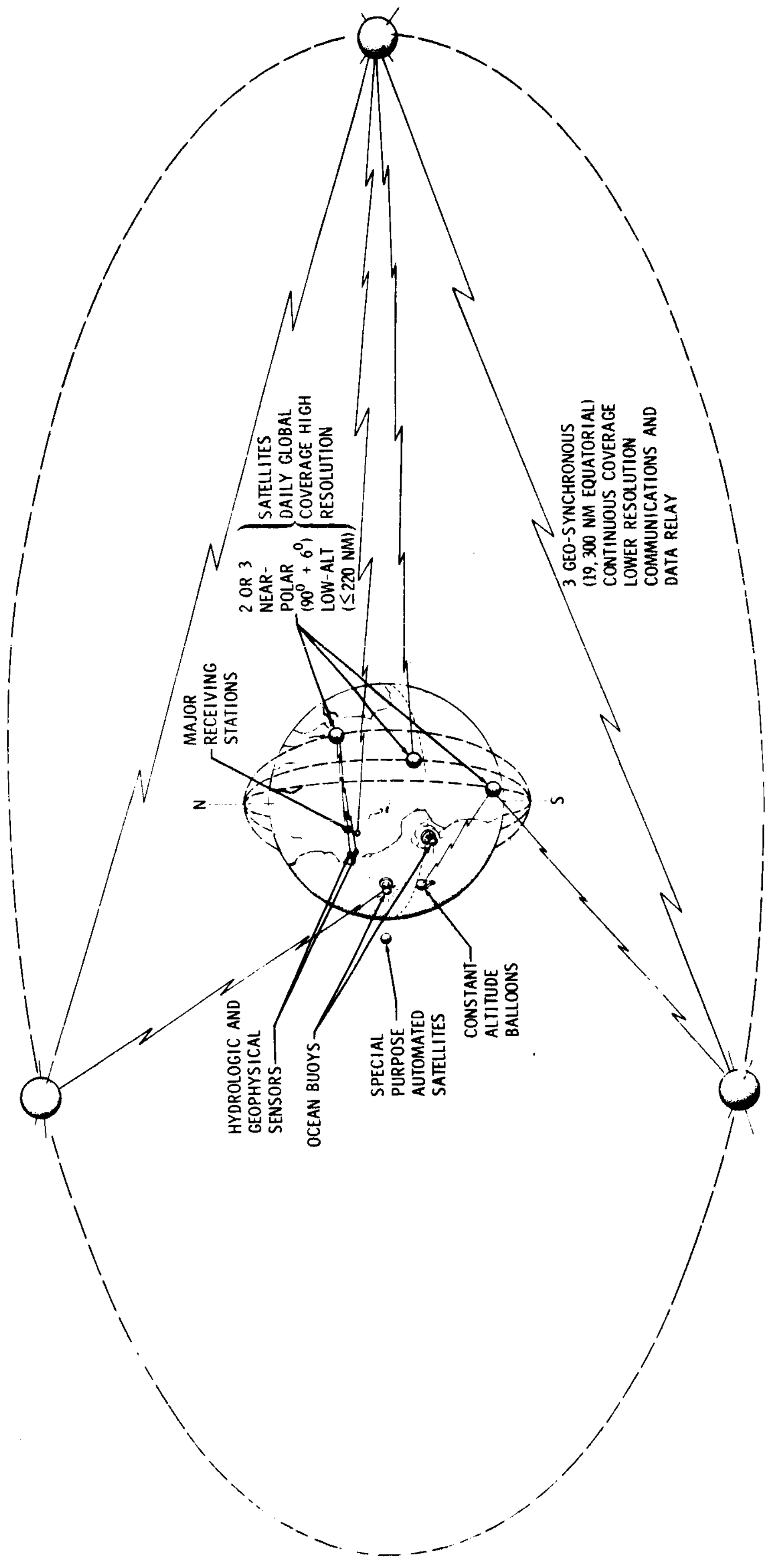


FIGURE III
COMPREHENSIVE EARTH SURVEY SYSTEM USING MANNED
OR MAN ATTENDED SATELLITES

costs would be due to the shuttle system necessary to keep the system manned and supplied. If one assumed that the space stations will support up to ten scientific and applications disciplines, costs of the order of $0.5 billion to $1 billion per discipline could be arrived at.

We assume that two manned near-earth, near-polar space stations operable by 1980 will cost $10 billion (using a common shuttle system for both stations). With a total payload capability of 10,000 lbs for one station, or 20,000 lbs for two stations, each space station facility of 10,000 lbs payload would carry a price tag of $5 billion.

Three geo-synchronous satellites are an important part of a manned applications payload. However, their greatest significance will probably lie in the fields of communications, meteorology and oceanography. A cost of $0.2 to 0.5 billion per 1,000 lbs of applications experiments appears adequate.

Then, a manned, Phase III space station system would cost about $15 billion for ten years. Of this expense, earth resources survey would be changed anywhere from $0.5 to 5.5 billion. Calculations can be made to support almost any point of view, but it is clear nevertheless that the cost per information bit of manned and unmanned systems does not show significant disadvantages for the manned program.

C. Equivalent Unmanned Phase III System

It is somewhat futile to project the costs for an unmanned system capable of delivering 10^{13} bpd, and requiring of the order of 100 launches over a ten year period. The Woods Hole figure of $1.4 billion as an investment in a four year operational program may be significant, leading to a ten year figure of about $3 billion.

This figure is similar to the expense projected for a manned system. Since this unmanned program will provide less data and less growth capability than the manned program, it seems less attractive on these counts.

VI. COMPARISON OF EQUIVALENT MANNED AND UNMANNED PROGRAMS

The advantages of the manned program lie in the pooling of large payloads of multidisciplinary sensors, thereby allowing commonality, versatility, repair, comparison,

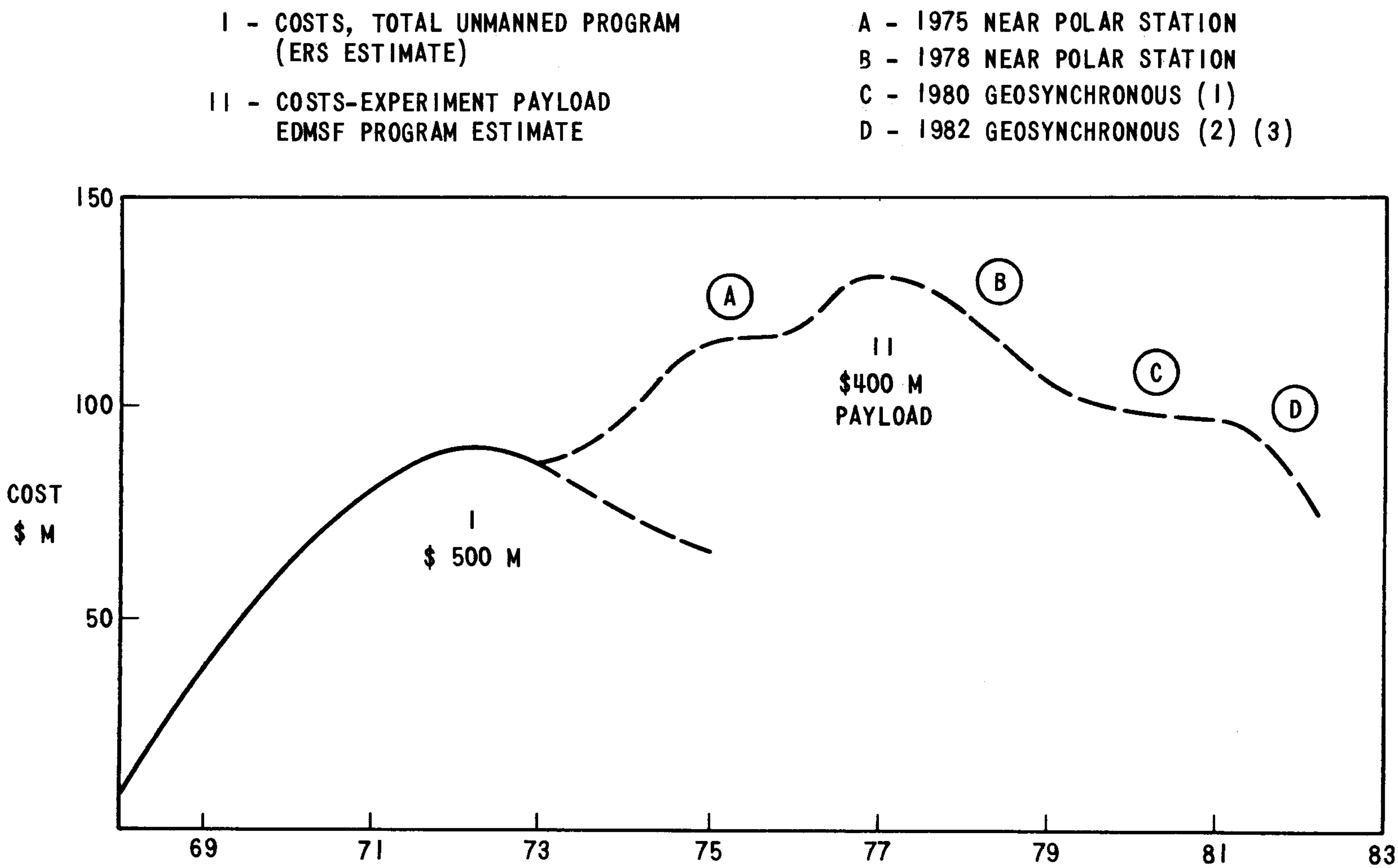


FIGURE IV - ESTIMATED COSTS, UNMANNED AND MANNED PROGRAMS trade-off and evaluation studies, and real-time communication with experts on the ground. The net effect of all this is rapidity of development, cost and weight efficiency and dependability.

Disadvantages are large commitments to operational systems with relatively few decision points after the initial word "go", long lead times and unwieldy programs due to a limited number of missions.

VII. CONCLUSION AND SUMMARY

This study finds that a maximum manned program to support earth applications:

1. Should consist of sensors grouped about two sets of manned stations; one set of two fully manned stations in low-altitude, near-polar orbit would provide the bulk of sensing requiring high resolution, daily coverage, and would serve as an R&D platform for future systems. The second set of three geo-synchronous satellites would be automated, man-attended, and would supply continuous low resolution monitoring and data relay functions.

2. These facilities can supply all the needs of a complete sensing program except for a few automated satellites in geodesy and perhaps meteorology, plus ground based sensors -- buoys, balloons and local aircraft.

3. The advantages of manned support are primarily rapid system development, versatile, long-lived maintainable systems, large payload and power capabilities, film return, and specialized manned studies and operations.

4. The long range program would be more costly than the automated program now planned (ERS) but could well prove more cost-effective when the entire system is operating, particularly if a strong manned program exists anyway to support other agency goals.

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Subpanel, Washington, D. C., March 28, 1969. Thanks are due to W. W. Elam for much of the information on meteorology, and to S. Shapiro on the coverage capabilities of polar orbiting satellites.

W. L. Smith

1015-WLS-caw W. L. Smith

Attachments
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Appendix Tables 1-3

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TABLE 2 APP: SPECIFIC REQUIREMENTS FOR EARTH RESOURCES SURVEY - PHASE II

Discipline	PHASE II ACHIEVABLE IN MIDDLE TO LATE 1970's	Resolution m	Size km^2	Freq. of Coverage Year	Total Bits Year	Bits/Day	Fraction of Satellite Capacity	ESTIMATED WEIGHT OF SYSTEM
Ag/For	Seasonal vegetation atlas 1:100,000	100	10^8	4	$4 \times 5 \times 10^{12}$	5×10^{10}	1	RBV Imager 200 lbs.
Ag/For	Production loss and yield increase chart	100	7×10^6	12	$12 \times 3.5 \times 10^{11}$	10^{10}	.25	RBV Imager 200 lbs.
Oceanogr.	Weekly thermal map of the oceans	1000	10^8	50	50×10^{11}	2×10^{10}	.5	IR Imager 200 lbs.
Oceanogr.	Weekly sea state over oceans	--	10^8	50	-	-	-	Scatterometer 300 lbs.
Oceanogr.	Weekly current map	1000	10^8	50	50×10^{11}	2×10^{10}	.5	IR Imager
Oceanogr.	Weekly sea state map	--	10^8	50	-	-	-	Scatterometer
Oceanogr.	Weekly sea pollution map	1000	10^7	50	50×10^{10}	2×10^9	.05	IR Multichannel 200 lbs.
Hydr.	Biweekly water inventory on land	100	7×10^6	100	$100 \times 3.5 \times 10^{11}$	10^{11}	2	RBV
Hydr.	Biweekly snow inventory	1000	10^6	50	$50 \times 5 \times 10^9$	10^9	.025	IR Imager
Hydr.	Biweekly flood control report	100	2×10^6	50	50×10^{11}	2×10^{10}	.5	RBV
Geogr.	Weekly pollution chart over continents	1000	7×10^6	50	$50 \times 3.5 \times 10^{10}$	5×10^9	.1	Absorption Spectr. 150 lbs.
Cart.	World wide map 1:0.5 mill	100	10^8	1/x	$1/x \times 10^{12}$	$1/x \times 10^{10}$	.2	RBV
Geogr.	Rural, urban development index	100	7×10^6	1	3.5×10^{11}	10^9	.025	RBV
						2.1×10^{11}	$5.15 \approx 5$	1,050 lbs. 1,050 lbs. support 2,000 lbs. payload

This phase requires 10 ERTS C/D with 1000 lbs. payload each.

TABLE 3 APP: SPECIFIC REQUIREMENTS FOR EARTH RESOURCES SURVEY - PHASE III

Discipline	PHASE III ACHIEVABLE IN FY 1980's to FY 1990's	Resolution m	Size km^2	Freq. of Coverage Year	Total Bits Year	Bits/Day	Fraction of Satellite Capacity	ESTIMATED WEIGHT OF SYSTEM
Ag	Biweekly agricultural crop vigor and stress reports	30	7×10^6	100	100×10^{12}	5×10^{11}	5.	RBL Imager 200 lbs.
Ag/For	Annual crop and timber forecast and census	30	10^8	1	3×10^{12}	10^{10}	.1	IR Multichannel (1) 200 lbs.
Oceanogr.	Biweekly sea state report	-	10^8	100	-	-	-	Scatterometer 300 lbs.
Oceanogr.	Biweekly current and temperature chart	1000	10^8	100	100×10^{11}	5×10^{10}	.5	IR Imager 200 lbs.
Oceanogr.	Biweekly biota and fish school schedule	100	10^7	100	100×10^{11}	5×10^{10}	.5	IR Multichannel
Oceanogr.	Weekly fish census	30	10^7	50	$50 \times 3 \times 10^{11}$	5×10^{10}	.5	Spectrometer (1) 200 lbs.
Oceanogr.	Weekly coastal pollution chart	100	10^7	50	50×10^{11}	5×10^{10}	.5	Absorption Nectrom. 150 lbs.
Oceanogr.	Fish catch projection	100	10^7	50	50×10^{11}	2×10^{10}	.25	IR Multichannel (2) 200 lbs.
Geol.	Yearly mineral exploration forecast	100	10^7	1	10^{12}	5×10^9	.05	IR Nectrometer (2). 25- lbs.
Geol.	Weekly soil moisture chart	300	7×10^6	50	$50 \times 3 \times 10^{11}$	5×10^{10}	.5	RBV Imager
Geogr.	Daily pollution chart	1000	7×10^6	300	$300 \times 3.5 \times 10^{10}$	3×10^{10}	.3	Absorption Spectrom.
Geogr.	Biweekly fresh water status	100	7×10^6	100	$100 \times 3.5 \times 10^{11}$	10^{11}	1.	RBV Imager
Geogr.	Update of world map 1:0.25 mill	30	10^8	1	3×10^{12}	10^{10}	.1	RBV Imager
Geogr.	Annual land use index	30	10^8	1	3×10^{12}	10^{10}	.1	RBV Imager
Geogr.	Monthly urban development chart	100	7×10^6	12	$12 \times 3 \times 10^{11}$	10^{10}	.1	RBV Imager
Geogr.	Daily air pollution chart	100	7×10^6	300	$300 \times 3 \times 10^{11}$	3×10^{11}	3	Absorption Spectrom.
Geogr.	Daily traffic projection for urban areas, harbors, airports, etc.	100	2×10^5	300	300×10^{10}	10^{10}	.1	RBV Imager
						$\sim 10^{13}$ bpd	12.6	1,7000 lbs. 1,7000 lbs. support 3,4000 lbs. payload

Phase III requires 40,000 lbs. payload

BELLCOMM, INC.

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